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GUIDEBOOK

FORTY-SIXTH ANNUAL CONFERENCE
OCTOBER 9-10, 1954

DEPARTMENT OF GEOLOGY
DARTMOUTH COLLEGE
HANOVER, N.H.

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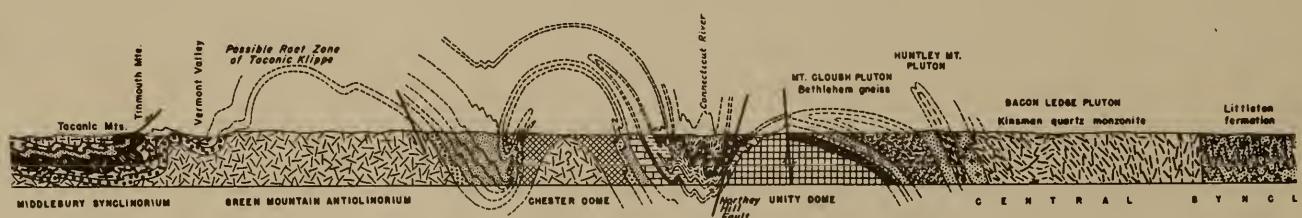
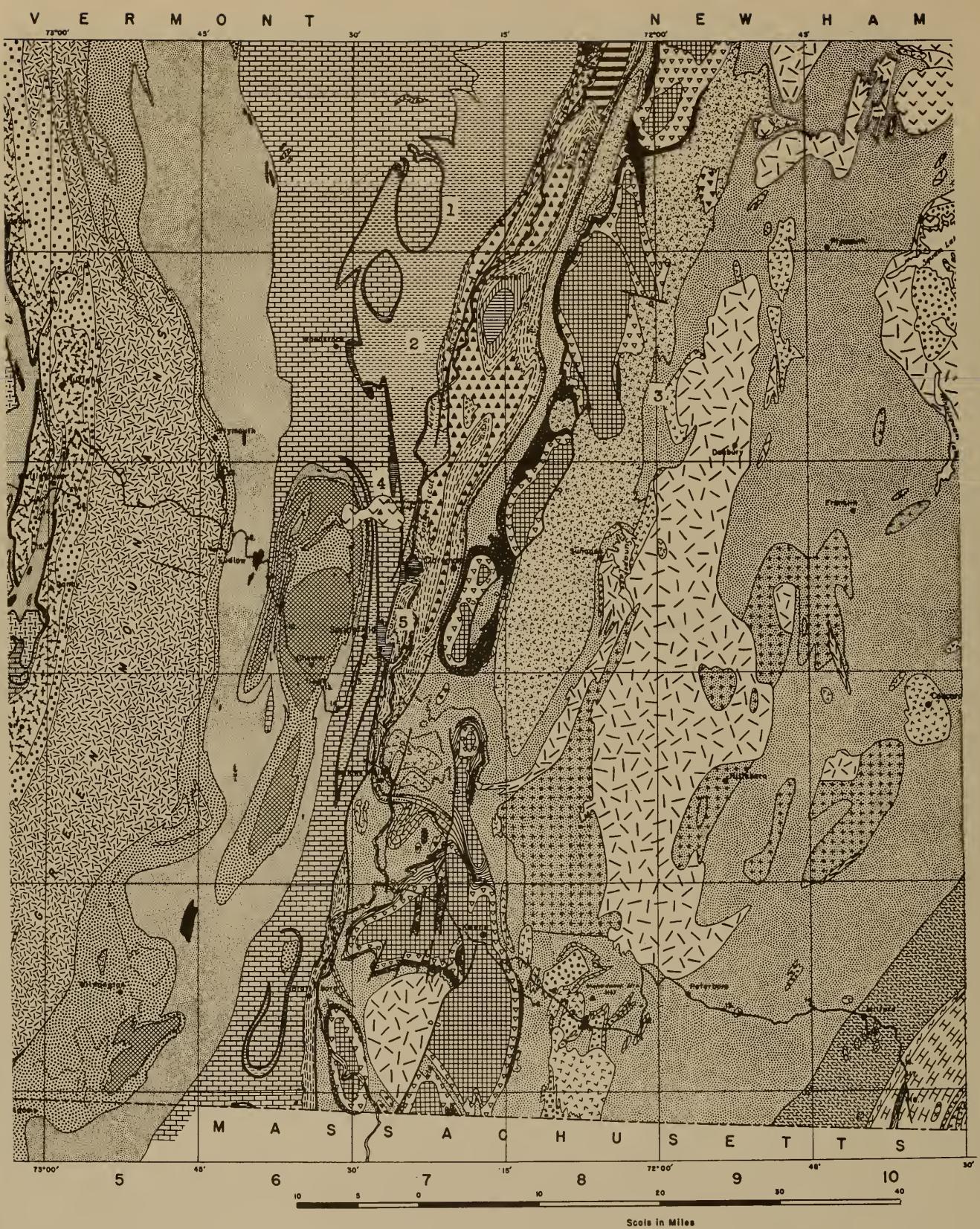
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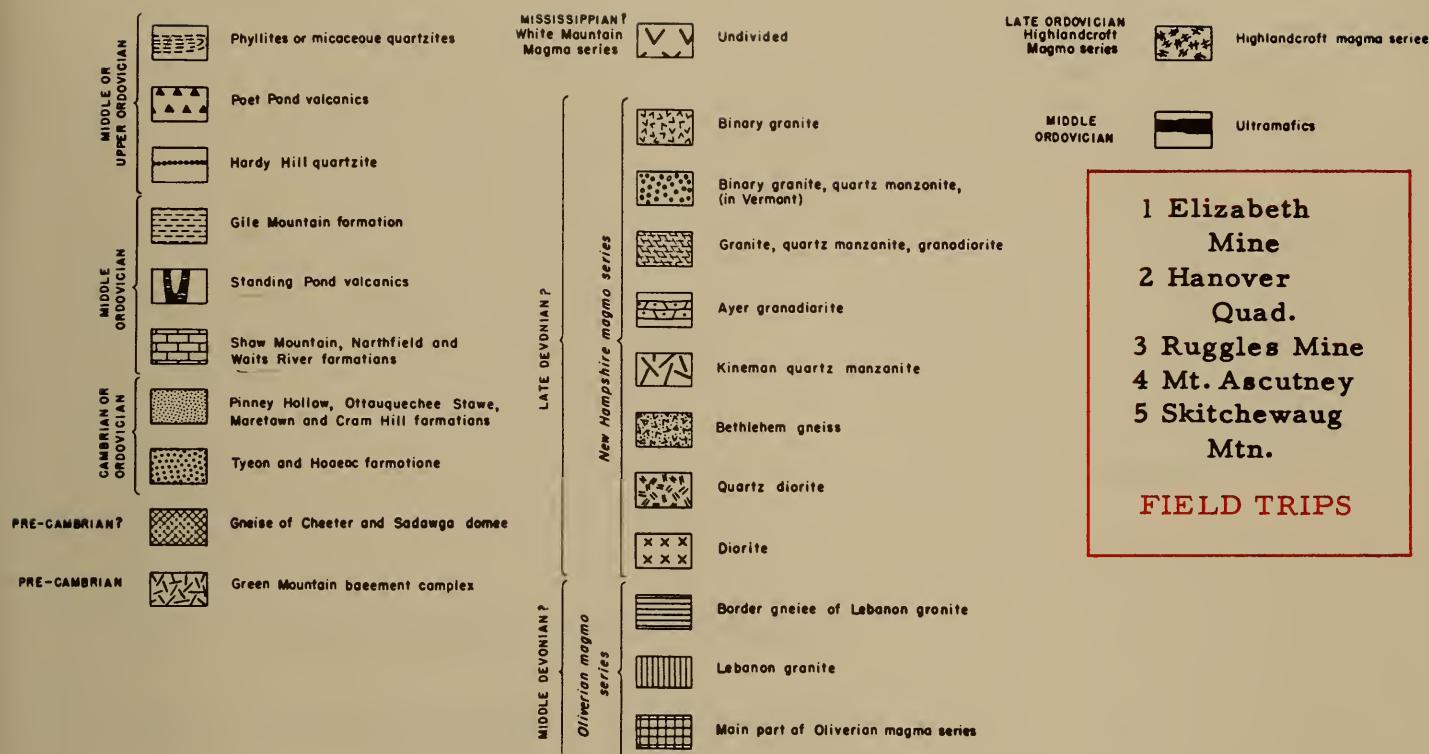
GUIDE BOOK
FORTY-SIXTH ANNUAL CONFERENCE
OCTOBER 9-10, 1954

DEPARTMENT OF GEOLOGY
DARTMOUTH COLLEGE
HANOVER, N. H.



SOUTHEASTERN VERMONT

PLUTONIC (AND VOLCANIC) ROCKS



METASEDIMENTARY AND METAVOLCANIC ROCKS
WESTERN AND CENTRAL NEW HAMPSHIRE



Map by
M. P. Billings
et al 1952

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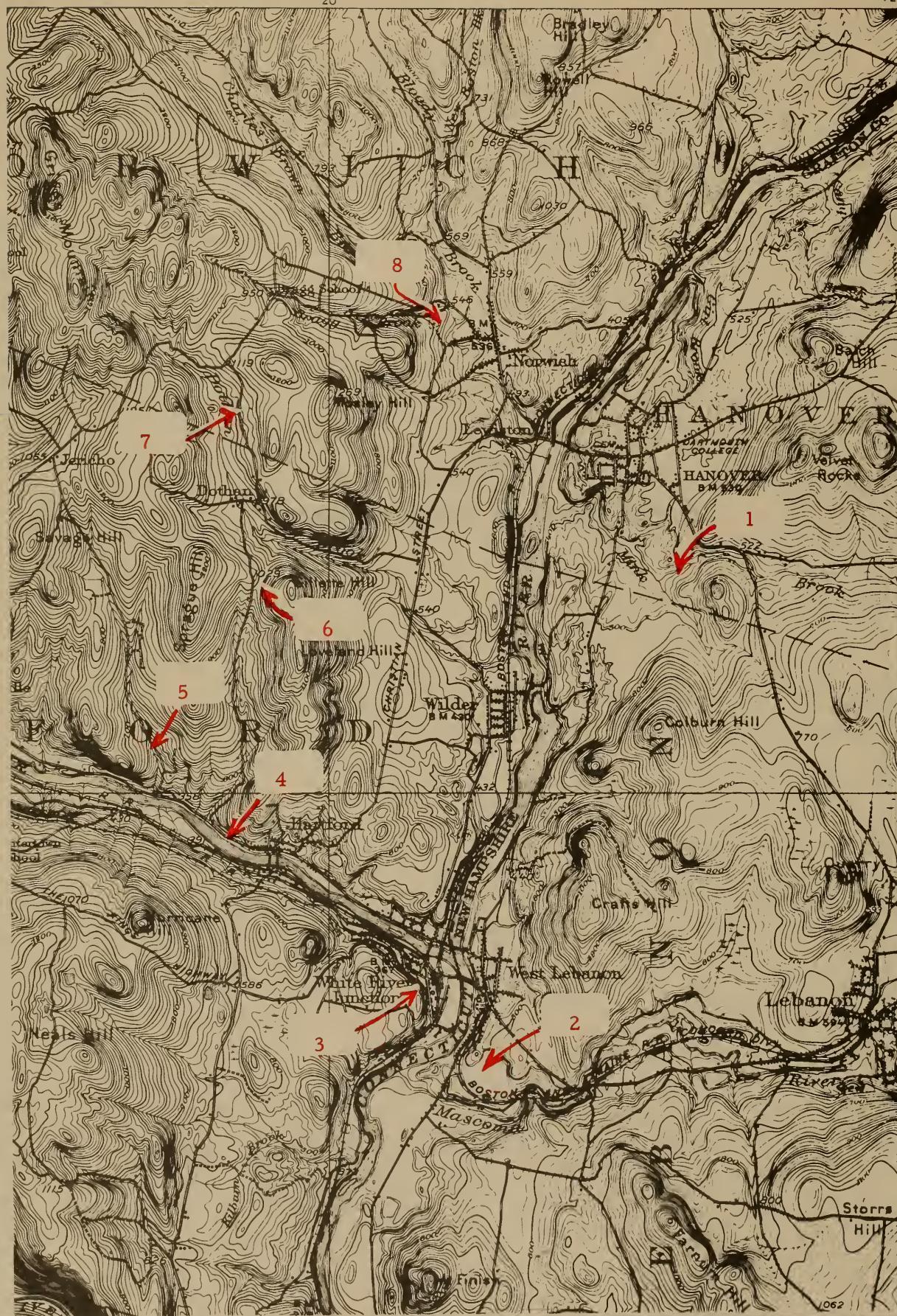
TRIP A

GLACIAL GEOLOGY OF THE HANOVER REGION

VERMONT-NEW HAMPSHIRE
HANOVER QUADRANGLE

15° (Mt Cuba)

Contour interval 20 feet



188 *Ascomyces*

134°
TRUE NORTH
MAGNETIC NORTH

APPROXIMATE MEAN,
DECLINATION 1906.

TRIP A

GLACIAL GEOLOGY OF THE HANOVER REGION - SATURDAY, OCTOBER 9, 1954, 8:30 A.M.

Leaders: E. D. Elston and A. L. Washburn

Assembly Point

In bus on Tuck Drive in front of Silsby Hall

STOP 1 North side of Mink Brook, Hanover, N. H., about 1/3 mile east of Route 10.ExposureStratified and, in part, laminated silt, sandy above
and clayey below

- - - - -

Note: This is Antevs' varved clay section #67, which he described as follows (Antevs, 1922, p. 29):

[Top]

25 feet sand and silt. Varve limits hardly distinguishable.
Varves 6806-7040, silty, often sandy and with lenses of sand.Varve limits often very difficult to distinguish. Thicknesses varying greatly, but on the average about 2 inches.
Varves 6760-6805, silty, distinct. Thickness varying from 1 to 15 inches.Exposed to the level of the brook. Depth to bottom unknown.
Series measured: (about 6760 to about 7040....)

See also following pages (Antevs, 1922): p. 58 (beginning with varves 6801-6903), p. 59 (to varves 7001-7073), p. 70, Fig. 3 opp. p. 5.

Questions:

1. Problems of varve identification and correlation.

STOP 2 Twin State Gravel Pit at south end of Elm Street, West Lebanon, N. H.ExposureTop

Coarse gravel and laminated silt at south end of pit

Till with many well-rounded stones at east end of pit,
grading westward into coarse, poorly stratified drift

Outwash at base of pit

- - - - -

Questions:

1. Age of laminated silt and relationship to other silt bodies in area.
2. Source and age of till.
3. Age of outwash.

STOP 3 Town of Hartford gravel pit, south side of White River at White River Junction, Vt.

Exposure

Top

Stratified silt and sand (not visible from base of pit)

Ice-contact stratified drift

- - - - -

Note: This stratified drift has been commonly interpreted as forming an esker extending, with breaks, approximately 50 miles along the Connecticut River from Bradford, Vt. (north of Hanover) to Windsor, Vt. (south of White River Junction, Vt.)

Questions:

1. Age of silt and sand and their relationship to other silt bodies in area.
2. Origin and age of ice-contact stratified drift.

STOP 4 North side of White River near Hartford, Vt., on Route 14, 0.2 miles east of junction with Dothan Road.

Exposure

Top

Laminated silt

Waterworn bedrock
(Gile Mountain formation)

- - - - -

Questions:

D

1. Age of laminated silt and relationship to other silt bodies in area.

STOP 5 East side of Jericho Road, 0.4 miles north of Route 14, near Hartford, Vt.

Exposure

Top

Till

Laminated silt, some sandy above and clayey below
Bedrock (in stream bed - Gile Mountain formation)

- - - - -

Questions:

1. Age of till and relationship to other till bodies in area.
2. Age of silt and relationship to other silt bodies in area.

STOP 5 (cont.)

Note: On northwest side of small stream paralleling Dothan Road, about 0.3 miles east of Jericho Road and 0.3 miles north of junction of Dothan Road with Route 14, there is a more extensive section but difficult of access for detailed study by a large group. The section here is as follows:

ExposureTop

Solifluction mantle (?)
 Stratified silt and gravel
 Till
 Stratified silt, contorted in places
 Stratified gravel
 Laminated silt
 Gravel

STOP 6 East side of Dothan Road, about 2 miles north of junction with Route 14.

U-shaped bedrock channel trending NNE-SSW, between Sprague Hill on west and Gillette Hill on east

Questions:

1. Origin and age of channel.

STOP 7 East side of valley of Dothan Brook about 1 mile north of Dothan. (Bus will stop near Dothan and we will have to walk approximately 1 mile to area).

Area of kame terraces

Questions:

1. Relationship of ice body recorded by kame terraces to U-shaped bedrock channel at Stop 6.

STOP 8 Gravel pit on south side of Bragg Brook Road near junction with Meadow Brook Road, Norwich, Vt.ExposureTop

Solifluction mantle (?)

Stratified sand and gravel with foreset beds dipping easterly (presumably constituting a delta built by Bragg Brook)

STOP 8 (cont.)

Note: The topography of the area immediately south and west of gravel pit is characterized by several benches.

Questions:

1. Origin of mantle overlying stratified sand and gravel.
2. Origin of benches.
3. Age of stratified sands and gravels and their relationship to lake or lakes in Connecticut Valley.

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TRIP B

STRUCTURAL GEOLOGY OF THE HANOVER REGION

↑
Devonian(?)
↓
↓
Ordovician(?)

Lebanon granite (lg, lb):

lg, Lebanon granite, a medium- to coarse-grained pink, subporphyritic, somewhat granulated granite and gneissic granite, composed of microcline, quartz, oligoclase, biotite, epidote, and muscovite. lb, border gneiss, a fine- to medium-grained, dark-gray, granulated quartz diorite gneiss; composed of oligoclase, quartz, biotite, epidote, microcline, hornblende, and muscovite.

Amphibolite (a):

Intrusive dark-green amphibolite composed of hornblende, andesine, and epidote.

Littleton formation (D1):

Black to gray quartz-mica schist.

Metamorphosed diabase:

Numerous sills and dikes of medium- to coarse-grained dark-green meta-diabase composed of sodic plagioclase, hornblende or chlorite, and epidote.

Gneiss (gn):

At White River Junction a lit-par-lit gneiss; banded gray gneiss composed of quartz, albite, and minor muscovite, chlorite, and epidote. Northeast of Plainfield a well-lineated gneiss composed of quartz, albite, chlorite, and epidote.

Hornblende gneiss (h):

Dark-green hornblende gneiss composed of hornblende, albite, and epidote. A thick meta-gabbro sill.

Orfordville formation (Oo):

Main part of formation, Oo, is gray, black, or tan quartz-mica schist or phyllite. Small volcanic lenses, Oov, composed of hornblende schist or chlorite schist. Hardy Hill member, Ooh, consists of gray to white quartzite and quartz conglomerate; small lentils of white calcite-quartz schist, Ooc. Post Pond volcanic member, Oop, consists of hornblende schist or chlorite schist. Locally, the Orfordville formation is converted to feldspathized gneiss, Oog.

Gile Mountain formation (Og):

Main part of formation, Og, consists of gray quartz-mica schist and quartzite. Lentils of dark-green hornblende schist, Ogh, of probable volcanic origin, consist of hornblende, oligoclase, and epidote. Black calcite-quartz schist, Ogc, Meetinghouse slate member, Ogm, consists of black phyllite.

Waits River formation (Ow):

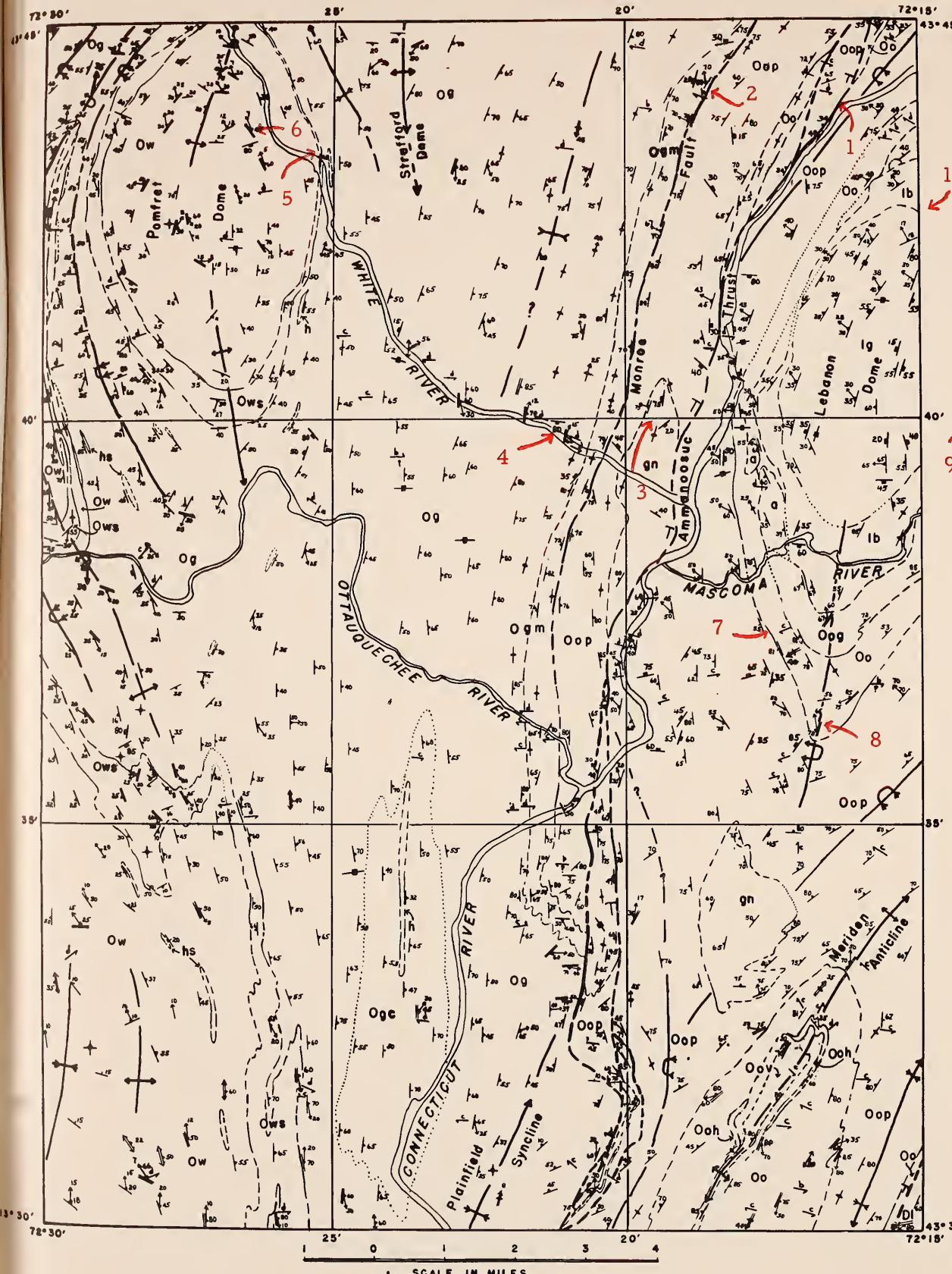
Main part of formation, Ow, consists of brown-weathering calcite-quartz schist with lesser amounts of gray mica schist. Lentils of hornblende schist, Owh, of probable volcanic origin, consist of hornblende, oligoclase, and epidote. Standing Pond amphibolite, Ows, is dark-green hornblende schist with some gray quartz-mica schist.

NOTE: Albee and Ammonoosuc formations (Ordovician) and Clough and Fitch formations (Silurian) are cut out by the Northey Hill thrust where the Orfordville and Littleton formations are in juxtaposition.

Meetinghouse slate is probably the equivalent of the part of the Orfordville formation below the Post Pond member.

LEGEND

STRUCTURAL SYMBOLS



Formation symbols as on
geologic map (Plate I)

↑ Devonian(?) ↓ Ordovician(?)

Lebanon
lg,
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Amphibol
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TRIP B

STRUCTURAL GEOLOGY OF THE HANOVER REGION - SATURDAY, OCTOBER 9, 1954, 8:00 A.M.

Leader: J. B. Lyons

Assembly Point

In buses on East Wheelock Street in front of Alumni Gymnasium.

General

The Hanover quadrangle of west-central New Hampshire and east-central Vermont straddles a belt of cleavage domes on the west and of Oliverian granitic domes on the east. The latter are represented within the area by the synkinematically intruded Devonian (?) Lebanon granite which has been forcibly injected upward and southeastward. Surrounding metamorphics have been granitized, and the beds south of the intrusive have been overturned. The cleavage domes are represented by the Pomfret dome, an unusual structure thought to be due to the uparching of already folded rocks by a rising granitic or migmatic massif.

Ordovician (?) eugeosynclinal metamorphics underlie most of the quadrangle. These consist of the "Vermont sequence" (Waits River and Gile Mountain formations), and the "New Hampshire sequence" (Orfordville formation). The latter is thought to overlie and be a partial equivalent of the Gile Mountain formation, but the evidence is not unequivocal. A revision of the stratigraphy of the Orfordville formation as first described by Hadley (1942) is also necessitated by the geologic relations within this quadrangle.

Three thrust faults disrupt the structure. Two of these, the Monroe and Northey Hill, are premetamorphic, and recognized only with difficulty. The third, the Ammonoosuc, is a clearly defined shear thrust.

STOP 1 West side of Connecticut River, on Route 5, 3 miles north of Lewiston, Vt.

Exposure

- 40' Chlorite-sericite schist (greenschist facies) of the Post Pond volcanic member of the Orfordville formation (Oop)
- 30' Brecciated zone of the Ammonoosuc thrust fault
- 45' Hornblende gneiss and quartzite (amphibolite facies) of the Post Pond volcanic member of the Orfordville formation (Oop)

- - - - -

Note: This is one of several exposures of the Ammonoosuc thrust in the Hanover quadrangle. The thrust dips westerly at 35° , and the hanging wall has slid easterly for a probable distance of several thousand feet.

The chevron folds in the upper block are apparently characteristic of the fault in this region.

STOP 2 Hill on west side of road, $1\frac{1}{2}$ miles north of Norwich, Vt.

Exposure

(east to west)

Chlorite schist (greenschist facies) of the Post Pond volcanic member of the Orfordville formation (Oop)

Monroe fault (?)

Pin-stripe schist. This may be an easternmost unit of the Meetinghouse slate member of the Gile Mountain formation (Ogm), the Orfordville formation (Oop), or possibly the Albee formation (Oal)

- - - - -

Note: These exposures are more or less typical of those along the projected trace of the Monroe fault. This fault, further north, has a west-side-up displacement, and separates rocks of the so-called "Vermont sequence" from the "New Hampshire sequence". There is no structural evidence of faulting in these outcrops and the Monroe fault, if present, must pass west of this hill. "Pin-stripe" schist is typical of the eastern third of the Meetinghouse slate at the type locality of that member in the Strafford quadrangle to the north; the western two-thirds is a black low-grade schist. Toward the southern portion of the Hanover quadrangle, the Meetinghouse slate member is increasingly arenaceous.

Pillow lavas at the crest of the hill indicate stratigraphically younger rocks to the west. If there is no fault, and the pin-stripe schists are a part of the Gile Mountain formation, the latter overlies the Orfordville formation. This is contrary to proposed stratigraphic correlations in the region. Other evidence indicates the probability that the Meetinghouse slate (Ogm) and lower Orfordville schists (Oop) are equivalent, and that the Gile Mountain underlies the Orfordville formation.

STOP 3 Christian Street, one mile northeast of Hartford, Vt.

Exposure

Sodaclase tonalite gneiss (gn) in lit-par-lit structure with chlorite schist of the Post Pond member of the Orfordville formation (Oop)

- - - - -

Note: Diabase dikes which elsewhere cut through this complex, and the complex itself, have been regionally metamorphosed to the greenschist facies. Its geologic relations and a zircon-method age determination (424 m.y.) indicate that the sodaclase tonalite is a member of the Highlandcroft magma series (Ordovician) (av. age 388 m.y.). This dates the Orfordville formation as Ordovician or older. If proposed stratigraphic relations are properly interpreted, the Gile Mountain formation would also be Ordovician or older.

STOP 4 Route 14, $\frac{1}{2}$ miles west of Hartford, Vt., on the White RiverExposure

Tightly-folded upper portion of the Gile Mountain formation (Ogm) in the greenschist facies (biotite zone)

- - - - -

Note: This outcrop has excellent examples of cleavages of several types, lineation, etc. Exposures at the east have two cleavages, one of them axial-plane, and the other bedding- or slip-cleavage. At the west end are good examples of reverse drag folds, probably produced by the rise of the Pomfret cleavage dome to the west. West of these outcrops the Gile Mountain formation becomes more arenaceous, and the cleavage gradually flattens toward the cleavage dome. The detailed structure of the Gile Mountain formation between these outcrops and those at Stop 5 is obscure.

STOP 5 Route 14, $\frac{1}{2}$ miles northwest of West Hartford, Vt.Exposure

(east to west)

Gile Mountain formation (Og): basal arenaceous beds

135' Standing Pond amphibolite (Ows); the uppermost member of the Waits River formation

Waits River formation (Ow): typical calcareous schist in the amphibolite facies (kyanite zone)

- - - - -

Note: On the west side of the Pomfret dome the Standing Pond amphibolite is 650 feet thick; toward the southwest it transgresses upward into the Gile Mountain formation. The amphibolite has no volcanic structures, and is probably a reworked volcanic tuff or flow.

Boudinage is pronounced in these outcrops, but the complex structure in the Waits River beds is not apparent.

STOP 6 Hill $1\frac{1}{2}$ miles N 45° W of Hartford, Vt.Exposure

Waits River formation (Ow) intruded by a small pegmatite vein

- - - - -

Note: Axial-plane cleavage in a series of easterly-dipping tight folds conforms to the structural pattern of the cleavage dome. At the center of the dome these folds are recumbent. Bean (1951) has detected low-density rock under the eastern side of the Pomfret dome, at an undetermined depth. Similar low-density rock occurs below the Strafford dome, to the northeast, at a depth of 2650 feet. The pegmatite suggests that the cause of the mass-deficiency is granite.

Structures in the Waits River formation are probably more complex than those in the overlying formations which have no outcrops of comparable complexity.

STOP 7 West side of Farnum Hill, 1 mile south of Routes 3 and 4, and 4 miles southwest of West Lebanon, N. H.

Exposure

(west to east)

Hornblende schist of the Post Pond volcanic member of the Orfordville formation (Oop) in the amphibolite facies (garnet zone)

Black garnetiferous schist of the Orfordville formation (Oop)

- - - - -

Note: The contact between these two stratigraphic units roughly follows the road southerly. Here as elsewhere the basal Post Pond is conspicuously calcareous. The distinctly higher grade of metamorphism of these rocks as contrasted with those at the next stop is striking. Rocks west of the Lebanon pluton are more highly metamorphosed than those east and south of it.

STOP 8 Pasture north of road, and one mile south of Farnum Hill, Lebanon, N. H.

Exposure

(east to west)

Post Pond volcanic member of the Orfordville formation (Oop) in the lower amphibolite facies

Black schist of the Orfordville formation (Oo)

- - - - -

Note: These outcrops are a few hundred yards east of the nose of a fold as outlined by the Post Pond member and the black schists of the Orfordville formation. The steep northwesterly plunge of major and minor structure is due to the overturning of an anticline by the forceful southeastward intrusion of the Lebanon pluton. The northern end of the pluton plunges gently northwestward. Thus its shape is that of an asymmetric cone, tilted northwesterly. The structure deduced from field observations has been confirmed by Bean's (1951) study of gravity anomalies around the pluton.

STOP 9 Hardy Hill (south slopes), Lebanon, N. H.

Exposure

Hardy Hill quartzite member of the Orfordville formation (Ooh) in the amphibolite facies. This is the type locality.

- - - - -

Note: Outcrops north of the road show graded bedding with tops west, but steeply-plunging minor folds and cleavage-bedding relations indicate tops east. The graded bedding is in agreement with regional stratigraphic and structural relations, and the folds are thought to be inverted. The Lebanon pluton lies to the west, and the Mascoma dome to the east. A couple

STOP 9 (cont.)

produced by the simultaneous rise of the Mascoma dome (upward toward the northwest) and the Lebanon pluton (upward toward the southeast) provides a logical explanation for the minor structures, and for the type of triaxial deformation recorded by the ellipsoidal conglomerate pebbles.

South of the road is a good outcrop of a Mississippian (?) diabase dike truncating the steeply-plunging folds.

STOP 10 Northeast slope of Velvet Rocks, Hanover, N. H.Exposure

Border gneiss (quartz diorite) (1b) of the Lebanon pluton (on the east)

Pink Lebanon granite (lg) (on the west)

- - - - -

Note: These outcrops are near the northern nose of the Lebanon pluton. Note the gentle dip of the foliate structures and the gentle northwesterly plunge of the linear structures; also the aplites which fill cross joints or are injected into foliation planes in the rocks. Although these outcrops are near a structural nose, the lithologic contact between the border gneiss and the granite trends southerly across the pasture, at a considerable angle to the foliation. These relations are suggestive that some of the foliate structure developed subsequently to the establishment of the lithologic contact, at a relatively late date in the intrusive history. Areal and petrographic evidence indicates that the border gneiss, in part, represents metasomatized Orfordville beds.

Age determinations by the zircon method for the rocks of the Lebanon pluton are as follows: granite - 330 m.y.; border gneiss - 321 m.y.; aplite 328 m.y. This would date them as late Silurian or early Devonian. Because they disrupt early Devonian rocks, field evidence favors this latter date.

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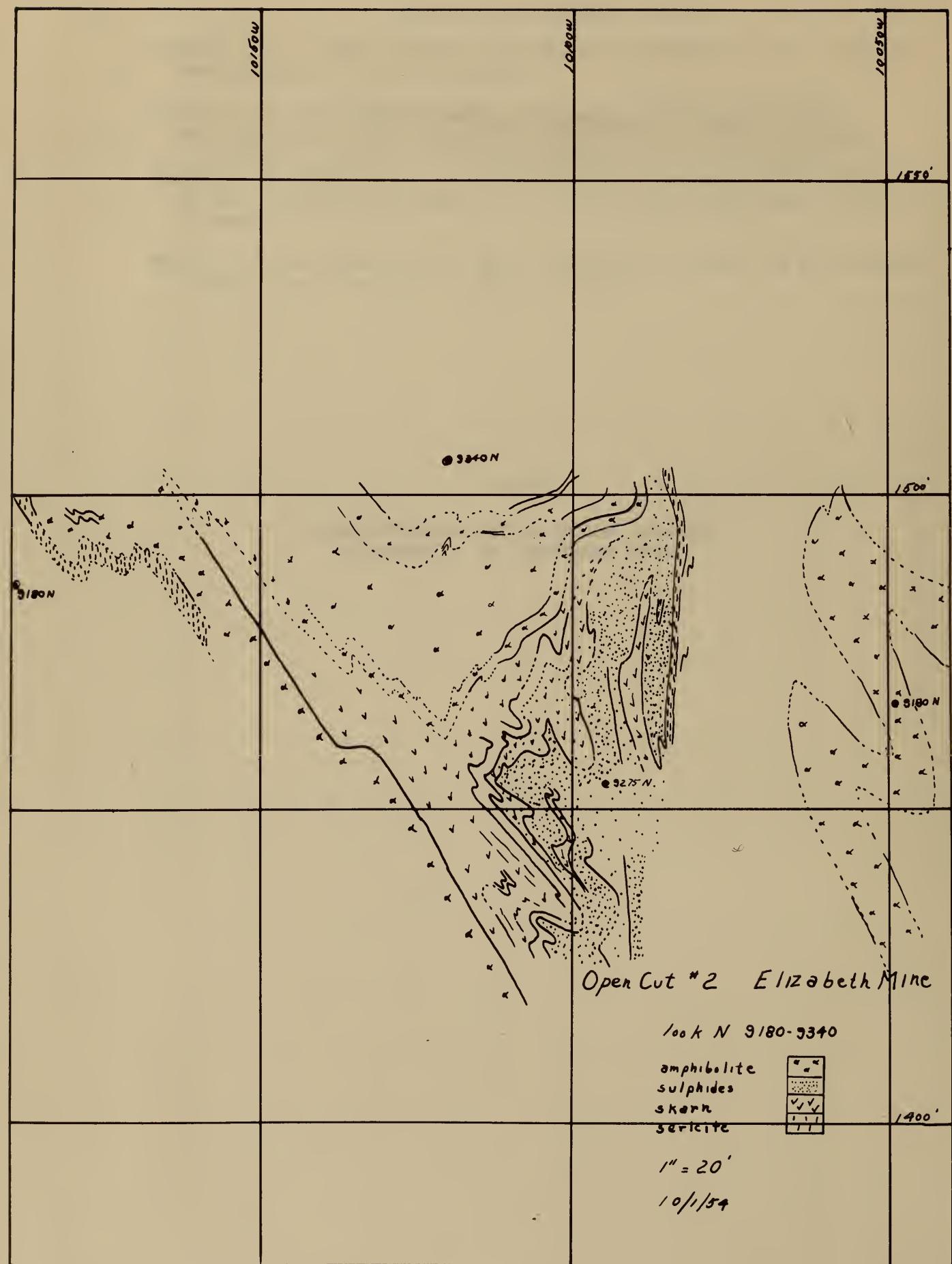
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TRIP C

ECONOMIC GEOLOGY OF THE ELIZABETH MINE,
SOUTH STRAFFORD, VT. (OPEN PIT)



TRIP C

ECONOMIC GEOLOGY OF THE ELIZABETH MINE,
SOUTH STRAFFORD, VT., (OPEN PIT) - SATURDAY, OCTOBER 9, 1954, 8:00 A.M.

Leader: H. E. McKinstry

Assembly Point

Tuck Drive in front of Silsby Hall, headed west.

Route from Hanover

Turn right, down Tuck Drive a few hundred feet from Silsby Hall, and cross the Connecticut River bridge. Turn right on Route 10A immediately after you cross the bridge. Continue north on 10A, which joins with Route 5. Follow 5 to the junction of Route 132, approximately 6 miles from Hanover. A sign at the junction points to the copper mine. Turn left. Proceed to the outskirts of South Strafford on Route 132. Turn left as indicated by a sign. At the end of this short road, turn left again and proceed to the mine offices.

General

The mine was discovered in 1793 but substantial production of copper did not start until 1830. From then on production was intermittent. In the present period of operation (1943 to date) three times as much copper has been produced as in all former operations.

The country rock is biotite schist of the Gile Mountain formation. Structure, is outlined by beds of hornblende-plagioclase rock ("amphibolite"), probably metamorphosed volcanic tuff. The orebodies are in the east limb of a structural syncline that plunges northerly an average of about 12 degrees. The fold is overturned, its axial plane dipping steeply eastward. The simplest interpretation is that there are two "amphibolite" formations in this fold, the rock between them being biotite schist and "skarn"--carbonate rock metamorphosed to tremolite-phlogopite schist. This and the adjoining biotite schist are replaced by sulphides. Adjoining the ore, biotite schist is altered to sericite schist and bleached. "Amphibolite" is altered to biotite and in extreme cases to sericite.

STOP 1 No. 2 Open Cut.

Looking northward into the open cut, the wall on your left is the "west-wall amphibolite", which is folded, forming also the overwall of the orebody. To your right, the wall is mostly "hangingwall amphibolite". Here you will find: Ore: Pyrrhotite and chalcopyrite, locally with much tourmaline and metacrysts of plagioclase. "Amphibolite": containing large garnets; also long radiating hornblende blades now altered to biotite in a matrix of sericite.

STOP 2 No. 1 Open Cut (not operating), 2000 ft. north of No. 2 Open Cut.

Looking north you can see a small synclinal fold of "amphibolite". The openings beneath it were parts of the orebody now mined out. From here the ore has been mined almost continuously on the northerly plunge for 6000 feet to a depth 975 feet below the open cut. The north end of the orebody is beyond the Pompanoosuc River. (You passed a raise beside the road along the stream as you came to the mine from Hanover.)

STOP 3 Mill.

The combined mine and open cut ore from the Elizabeth mine is reduced from a maximum size of 25" x 40" to a finished product minus either a 3/4" square or a 1/2" x 2 1/2" rectangular screen openings by using an integrated combination of two Blake type and one gyratory type crushers plus the required grizzlies, vibrating screen and inter-connecting conveyors.

To prepare the ore for further treatment it is ground wet in a #96 Marcy grate type ball mill, using 3" steel grinding balls and operating in closed circuit with a 78" Wemco spiral classifier. During the grinding, solutions of milk of lime and cyanide are added to the mill stream as a start in the separation of the copper and iron containing minerals from the gangue minerals.

In the Elizabeth ore, the mineral of most importance is chalcopyrite and of lesser importance is the pyrrhotite which at this time is valuable only because it contains sulphur used in other industrial plants. The most objectionable minerals from the mill man's point of view are muscovite, phlogopite and sericite or as they are called in the mill, mica and talc.

The average assays of the mill heads, (ore), concentrates produced and the tailings for the past three months are as follows:

	Oz. Ag.	% Cu.	% Insol	% Zn.	% Fe.
Mill Head	0.17	1.67		0.59	21.8
Cu. Concentrate	2.57	24.21	9.27	1.19	31.2
Mill Tailing	0.017	0.166		0.49	20.8
	% Fe.	% S.	% Insol	% Cu.	% Zn.
Fe. Concentrate	53.82	36.16	5.84	0.59	0.89

It will be noted from the above assays that the iron content of the ore is high. Nearly all the iron in the ore is contained in the pyrrhotite and the rejection of this mineral along with the mica and talc from the copper flotation circuit is the main problem in the milling of the Elizabeth ore.

The beginning of the pyrrhotite rejection starts in the grinding circuit and the use of additional lime to maintain a pH of 9.0 to 9.3 is used in the cleaning operations of the copper rougher concentrates. Using an excessive amount of either lime or cyanide effects the flotation of the chalcopyrite and usually results in a higher copper tailing and hence a lower recovery of the chalcopyrite.

STOP 3 (cont.)

To increase the flotation of the copper, a promoter in the form of a zanthate solution is added to the mill stream and this reagent plus the use of a pine oil - alcohol mixture produces a froth that gives us the desired condition for the flotation of the chalcopyrite. The excessive use of any of the foregoing reagents will cause the pyrrhotite to float and result in the production of low grade copper concentrates.

The so-called mica and talc minerals are easily floated with the same reagents used in the copper flotation. Partial rejection of these two minerals is accomplished in the cleaner operations by the use of suitable reagents known for their depressant effects on the flotation of the two minerals. However, the addition of a small amount of the reagent used will cause a costly rejection of the chalcopyrite.

Of all the minerals in the Elizabeth ore the most interesting one is the pyrrhotite, which causes complications in the flotation plant. It is known that some of the ore containing pyrrhotite oxidizes very rapidly and likewise probably reacts with other chemicals used in the flotation of the chalcopyrite.

Proof of this is seen from time to time in flotation of the pyrrhotite. The flotation of this mineral is accomplished by using sulphuric acid to bring the pH down to 6.2 - 6.6. At this point the addition of suitable promoters, collectors and frothing reagents will cause the pyrrhotite to float and produce very good metallurgical results. At times the pyrrhotite will not float in an acidified pulp and the pulp must be made alkaline. At times it is practically impossible to float the pyrrhotite under any conditions.

Some days the pyrrhotite concentrate produced will have a tendency to oxidize very rapidly and even start burning by spontaneous combustion after being stored less than 48 hours. All the pyrrhotite concentrates will oxidize and eventually catch fire but in some cases it takes up to ten days storage before this takes place. It has been noted that some of the pyrrhotite ores are magnetic and others are not. It has not been determined whether the foregoing characteristics of the pyrrhotite are responsible for the erratic results obtained from the concentration of the ore by flotation.

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TRIP D

GEOLOGY AND MINERALOGY OF THE RUGGLES MINE,
GRAFTON, N. H.

29

TRIP D

EOLOGY AND MINERALOGY OF THE RUGGLES MINE, GRAFTON, N. H. - SATURDAY, OCTOBER 9, 1954, 1:30 P.M.

Leader: A. H. McNair

Assembly Point

Tuck Drive in front of Silsby Hall, headed east toward Baker Library

Route from Hanover

Follow Route 4 from Lebanon southeastward 20 miles to Grafton Center (Cardigan Station), turn right at Brewster's Gun Store and proceed westward for 1.4 miles, turn right and cross bridge at Whitehall Co. gate and continue 1.5 miles to the mine.

General

The location of the Ruggles pegmatite is shown as locality 3 on the areal geologic map in the front of this Guidebook. The pegmatite occurs in the Littleton formation a short distance east of the hangingwall contact of the Bethlehem pluton. Small and large masses of Concord granite are exposed south and east of the pegmatite. The body is one of a swarm of pegmatites formed in a similar geologic setting and probably is genetically related to the Concord granite rather than to the Bethlehem gneiss.

Description of the Pegmatite

The most recent description of the Ruggles feldspar-mica mine is by J. J. Page (in Cameron et al., 1954, p. 235-240, Pls. 33-34), and the following brief statement has been taken largely from this source:

The wall rocks at the mine are medium-grained quartz-mica schist, coarse-grained biotite gneiss, and amphibolite of the Devonian Littleton formation. The schist is rich in biotite except near the pegmatite contacts where muscovite and black tourmaline are abundant. Scattered sillimanite and staurolite crystals occur in some schist lenses. Commonly the schist is drag-folded and minutely crumpled near the contact. Small basic dikes from 1/2 inch to 3 feet in thickness cut the pegmatite.

The pegmatite crops out for 1,640 feet along its strike. The maximum outcrop width is 335 feet and it ranges from a few feet to at least 160 feet in thickness. It strikes N. 35 E., approximately parallel to the strike of wall rock foliation. The body is an irregular lens that has not been deeply eroded. It is doubly plunging. Two prominent bulges occur along the eastern wall.

Internal Structure: Page identified 13 units in the pegmatite, only the most prominent of these will be mentioned below:

(1) The border zone consists of aplitic plagioclase (An_7), quartz, and muscovite, and ranges from 0 to 40 feet thick.

(2) The sheet-mica-bearing quartz-plagioclase (An_2) intermediate zone is discontinuous along the outer margin of the body. Muscovite is the most abundant mineral and commonly makes up 50 to 75 per cent of the unit. The mica books are large and are commonly oriented normal to the outer margin of the zone. It was this zone that furnished most of the sheet mica in the old workings at the south end of the mine.

(3) The "biotite" zone consists of plagioclase (An_{4-5}), perthite, quartz, biotite, and tourmaline. It formed a thick saddle-shaped capping that was exposed at the original outcrop surface and was broken through in 1935 to expose the perthite zone beneath it. Most of the unit has been removed since 1935, although it is prominently exposed at the sides and top of the north adit.

(4) The sheet-mica-bearing intermediate zone lies adjacent to the No. 2 feldspar zone, and consists of plagioclase (An_2), muscovite, quartz, and perthite. Mica-rich shoots were mined during World War II. Part of the zone is exposed on the west wall of the present cut.

(5) The No. 2 feldspar zone consists of perthite, quartz and plagioclase. It has a maximum thickness of 120 feet and completely enclosed the No. 1 'spar zone. It consists largely of perthite with abundant plagioclase and quartz. The perthite is commonly graphically intergrown with quartz. This unit is the chief source of feldspar in the floor of the present cut. Scattered clusters of green beryl crystals occur in this zone at the margin of the No. 1 zone.

(6) The perthite, or No. 1, zone was a large lens at least 450 feet long, 60 feet wide and 50 feet high. It was the principal source of No. 1 feldspar and has almost been mined out. Some of the perthite masses were giant crystals 25 x 12 x 10 feet as shown by continuity of cleavage planes. Patches of uranium minerals, for which the Ruggles mine is famous, occurred most abundantly along the top and sides of the perthite zone. Recent operations have not been in this part of the pegmatite and as a consequence radioactive minerals do not appear as common specimens on the recent dumps.

(7) Gray to milky quartz bodies occur in irregular lenses associated with the No. 1 feldspar zone and in late crosscutting veins and stringers. In the vicinity of radioactive minerals the quartz is smoky.

(8) Scrap-mica bearing replacement bodies occur at several places in the inner part of the pegmatite. These consist of small greenish wedge-shaped books that have a random orientation. They have been a source of a limited amount of scrap-mica.

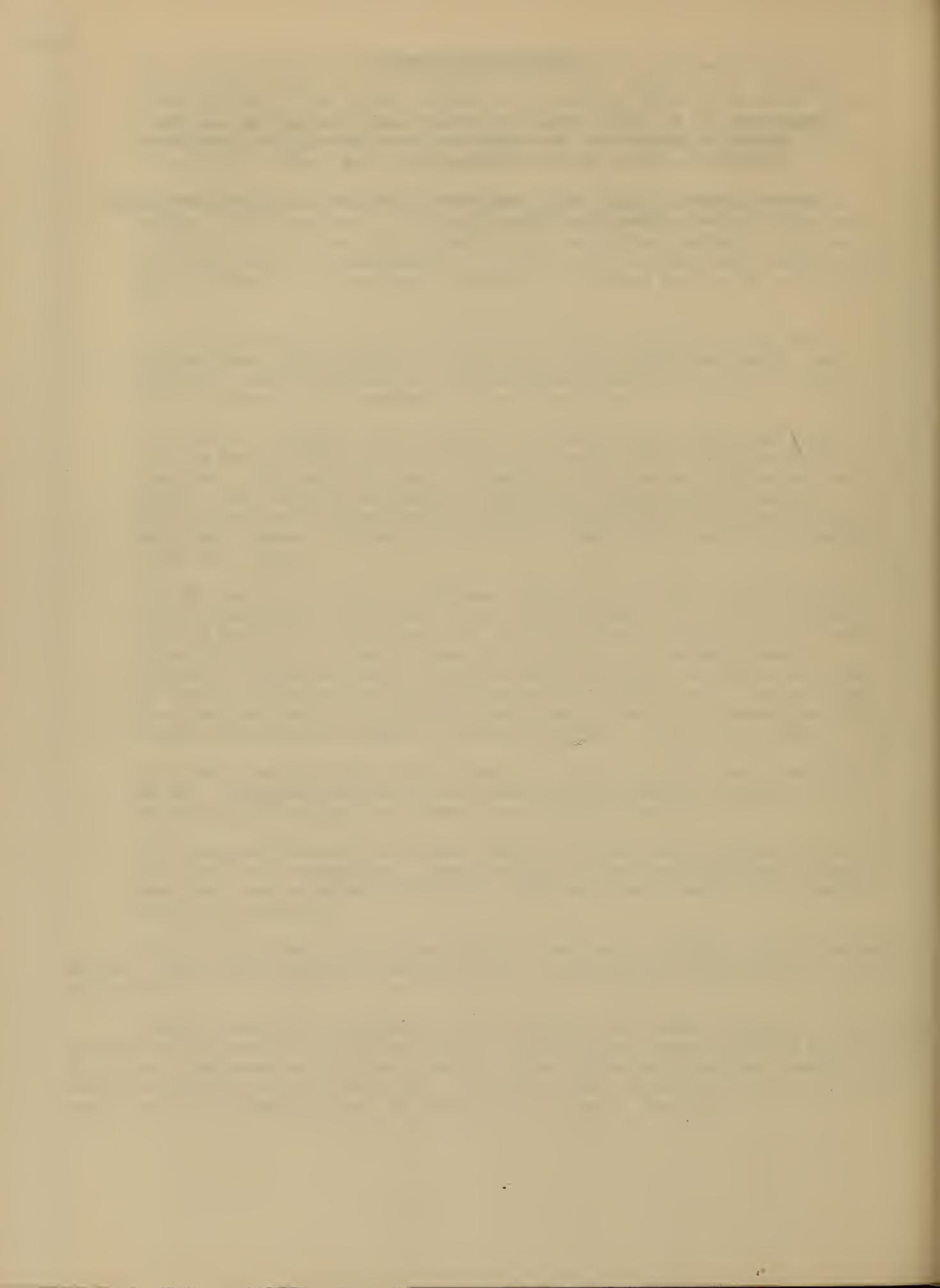
Although the chief product since 1935 has been No. 1 feldspar used in the manufacture of Bon Ami, considerable amounts of No. 2 feldspar has been produced for use in ceramics.

Sizeable reserves of feldspar and mica underlie the present workings. These were blocked into reserves by diamond drilling in 1946-47 when a number of holes were drilled in the north and south ends of the pegmatite. The central part had been penetrated by four exploratory holes drilled in 1940. A plastic model showing the structure of the lower part of the pegmatite will be available for study at the mine.

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TRIP E

STRUCTURAL GEOLOGY OF THE SKITCHWAUG
MOUNTAIN AREA, CLAREMONT QUADRANGLE, N. H. - VT.

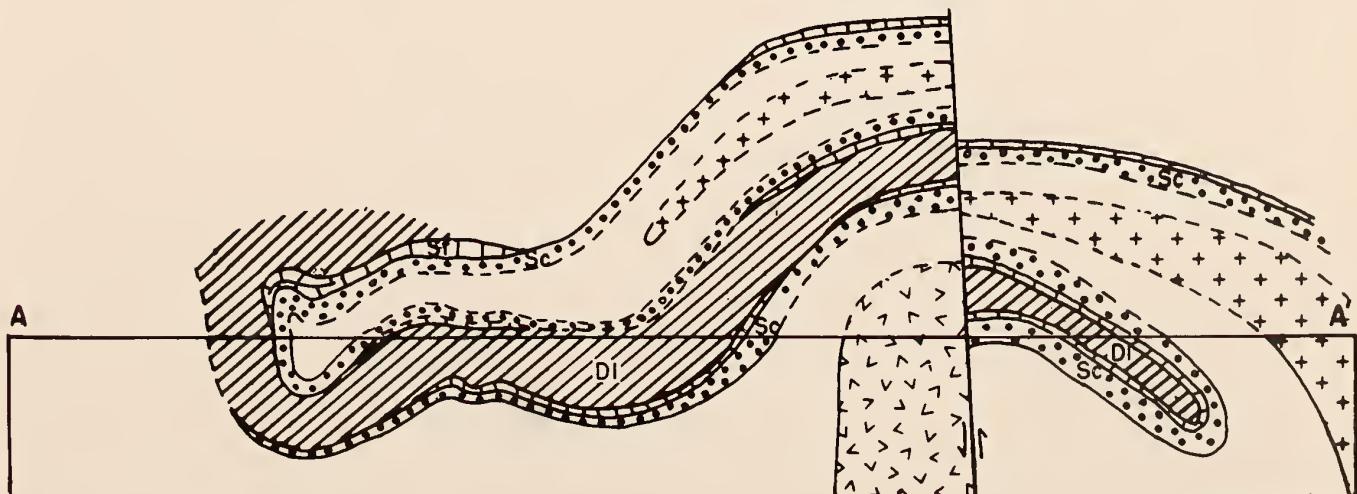
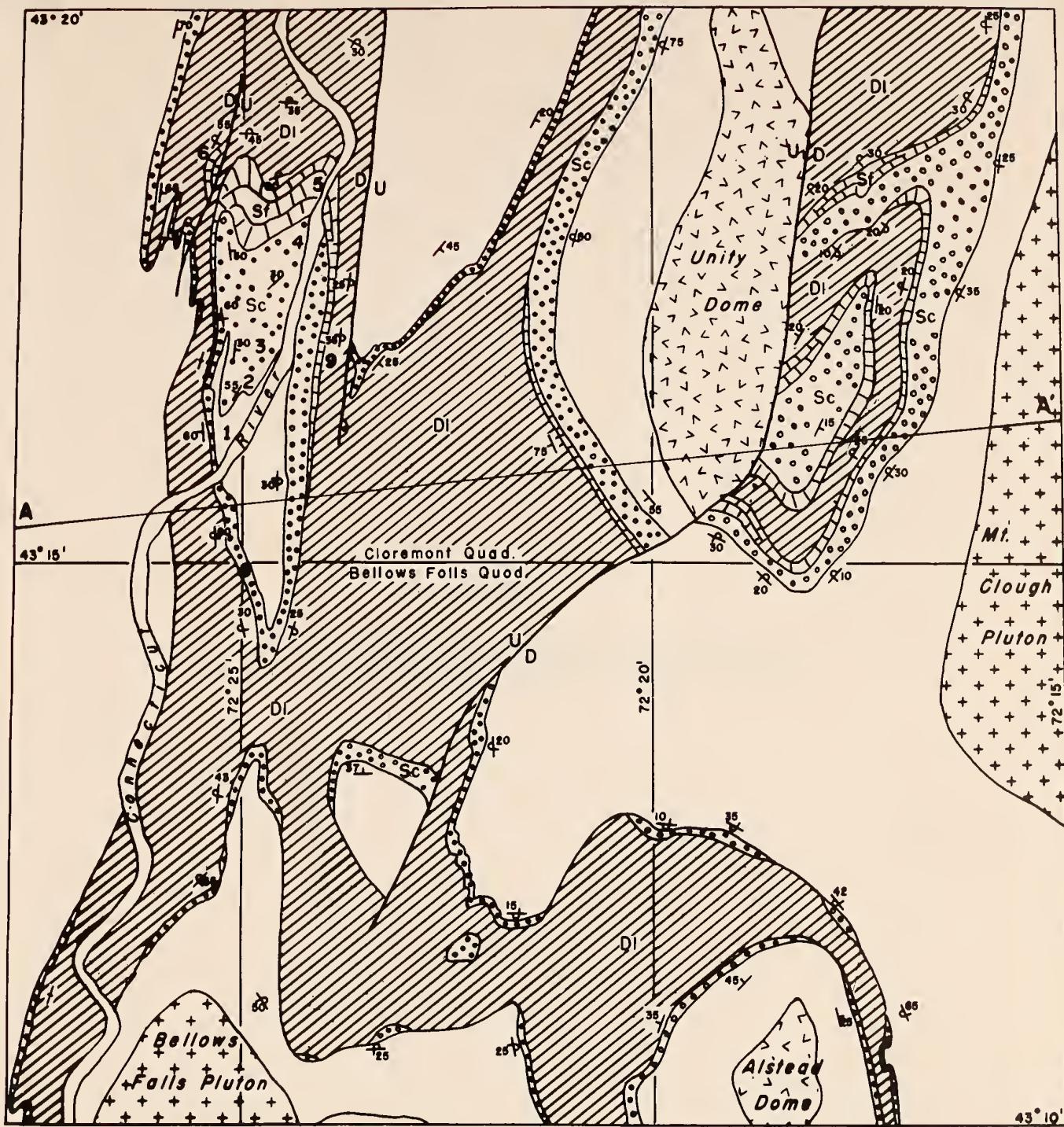
GEOLOGIC SKETCH MAP OF SKITCHWAUG NAPPE AREA

LEGEND

-  Bethlehem gneiss
-  Oliverian gneiss
-  Littleton formation
-  Fitch formation
-  Clough formation
-  Formations older than the Clough, chiefly Partridge formation and Ammonoosuc volcanics
-  Strike and dip
-  Strike and dip of overturned beds
-  High angle fault

Geology by J. B. Thompson, 1954,
based in part upon maps by
C. A. Chapman, 1942 and
F. C. Kruger, 1946.

0 1 2 3 miles



STRUCTURAL GEOLOGY OF THE SKITCHWAUG MOUNTAIN AREA,
CLAREMONT QUADRANGLE, VERMONT - NEW HAMPSHIRE

SUNDAY, OCTOBER 10, 1954, 8:30 A. M.

Leader: J. B. Thompson

Assembly Point

Ascutney, Vermont, at the junction of Route 5 with Routes 131, 12, and 103.

Ascutney is 21 miles south of White River Junction and 26 miles south of Hanover, on the Vermont side of the Connecticut River.

General

The discovery, in the spring of 1950, of a fossiliferous quartzite on Skitchewaug Mountain in Springfield, Vermont, has cast new light on certain of the stratigraphic and structural problems of southwestern New Hampshire and southeastern Vermont.

Subsequent detailed mapping in that area has shown that the fossiliferous quartzite of Skitchewaug Mountain is equivalent to the upper part of the Clough formation as mapped by Chapman (1939, 1942, 1952), Kruger (1946), and Moore (1949) along the flanks of the Bronson Hill anticline to the east. The fossils are deformed and metamorphosed (garnet and staurolite zones) but sufficiently well preserved to indicate a Silurian or early Devonian age, corroborating the correlations made by the above authors with the fossiliferous rocks at Littleton, N. H., to the north, and at Bernardston, Mass., to the south.

The unique feature of the Skitchewaug Mountain rocks is their structural relation to surrounding areas. The quartzites and associated rocks crop out over an area about five and one half miles wide and five and one half miles long on both sides of the Connecticut River in Springfield, Vt., and Charlestown, N. H. The pattern on the map is that of an arrowhead pointing south. The barbs of the arrowhead mark the "leading edge" or nose of a major recumbent anticline in the quartzites. The trend of this "leading edge" is here nearly east-west. The quartzites between the barbs, where the shaft of the arrow would fit, are on the upper limb of the recumbent anticline or nappe and in normal stratigraphic order or "right side up". It is noteworthy that the only recognizable fossils are confined to this area. The quartzites outlining the point of the arrow are on the under limb of the nappe and are consequently in inverted stratigraphic order. The various stratigraphic units appear to be thinner here than on the upper limb. That this thinning may be largely tectonic is suggested by the marked flattening and elongation of the cobbles in the basal conglomerate of the quartzite here as compared to that on the upper limb. The present map-pattern has been brought about by the superposing of an open synclinal fold with a north-south axis upon the structure just described.

Revision, during the past field season, of portions of the Bellows Falls area adjacent to the south has shown that the Bellows Falls pluton of the Bethlehem gneiss is surrounded by a band of the same quartzite, dipping beneath the gneiss in inverted position. These quartzites come within less than a mile of those of the Skitchewaug area in the hills just east of Charlestown village and were clearly continuous with

them at one time. A third area of inverted quartzites appears to the east in the area between the Alstead (Kruger, 1946) and Unity (Chapman, 1942) domes of the Bronson Hill anticline. Although cut out by a later normal fault in the north part of the Bellows Falls quadrangle for about two miles, these quartzites may be traced north into the Claremont and Sunapee quadrangles where they dip east (still inverted) beneath the Mt. Clough pluton of the Bethlehem gneiss, and south along the east side of the Alstead dome. The logical interpretation seems to be that the Skitchewaug area and the Bellows Falls pluton area outline a large nappe rooting east of the Bronson Hill anticline in the area of the Mt. Clough pluton, with the Bethlehem gneiss forming the core of the nappe. This interpretation lends support to the proposal of Kruger and Linehan (1941) that the Bellows Falls and Mt. Clough plutons were once connected over the crest of the Bronson Hill anticline.

The conspicuous ledges of quartzite and conglomerate in the Skitchewaug area have attracted the interest of geologists for some time. Galen D. Hull (1890) mapped the New Hampshire part of the area while a student at Dartmouth College and interpreted many of the structural relations correctly, although not recognizing the inversion of the stratigraphic sequence. C. H. Hitchcock (1912), noting similarities to the fossiliferous rocks at Littleton and Bernardston, suggested a Devonian age for the quartzites, though no fossils had been found at that time, and C. H. Richardson (1930), apparently noting the dissimilarity with other rocks in southeastern Vermont, raised the question: "Does Skitchewaug Mountain represent a fault block that has been thrown to the west of the Connecticut River from New Hampshire?" The writer is grateful to C. A. Chapman and J. C. Ratte, who have worked in the area more recently, for access to their findings. The writer has been mapping in the area intermittently since 1950 and work is still in progress.

STOP 1 0.8 miles north of the west end of the Cheshire Toll Bridge on Route 5.

Exposure

Outcrop on west side of road is dark muscovite-biotite schist of Partridge (?) formation. At the south end of the exposure is an amphibolite dike cutting across the schistosity.

Note: The schists of the Partridge formation generally contain pyrite or pyrrhotite and are characteristically rusty-weathering in contrast to those of the Littleton formation. The Partridge formation is the oldest rock exposed in this portion of the nappe.

STOP 2 0.5 miles north of Stop 1.

Exposure

Ledges west of road are basal conglomerate of Clough formation.

STOP 3 0.7 miles north of Stop 2.

Exposure

Interbedded pebbly quartzites and garnet-bearing mica schists in the central part of the Clough formation.

Note: Notice fold with axial plane trending nearly east-west and dipping south.

STOP 4 1.2 miles north of Stop 3.

Exposure

West of road are quartzites in the upper part of the Clough formation.

Note: Rusty-weathering calcareous bands in quartzite contain numerous highly deformed fossils and fossil fragments. Recognizable remains are chiefly crinoid stems and corals, but brachiopods, a cephalopod and a possible trilobite have also been found. The fossils have been studied by Dr. A. J. Boucot of the U.S.G.S. who will be present on the excursion. Just south of the principal road cut, a large mafic dike, now metamorphosed to epidote-amphibolite, cuts across the quartzites.

STOP 5 0.5 miles north of Stop 4.

Exposure

Road cuts in calcareous rocks of the Fitch formation. Characteristic types include quartz-calcite-biotite schist and calcite-actinolite granulites.

STOP 6 About 2.0 miles north of Stop 5 turn sharply left on Vermont Route 10 (Skitchewaug Trail), and proceed southwest about 1.5 miles to picnic table on right hand side of road.

Exposure

An inverted contact between the Fitch and Littleton formations is exposed in a cut on the southeast side of the road.

Note: On the hill above, exposures of the Fitch formation show characteristic pitted weathering. In the pasture grey sandy phyllites of the Littleton formation show easterly plunging folds. The exposures at Stop 6 are on the under limb of the Skitchewaug nappe, but close to the axial plane, and are just west of the axis of the open syncline superposed on the nappe.

STOP 7 About 1.0 miles south of Stop 6, at Spencer School.

Exposure

Conglomerate east of the road is believed to belong to the Clough formation on the under limb of the recumbent syncline beneath the Skitchewaug nappe (a recumbent anticline).

Note: Notice steeply plunging folds with sinistral pattern.

STOP 8 Proceed south on gravel road from Stop 7 for about 2.5 miles to junction with Vermont Route 11. Turn left (east) on Route 11 and proceed to Charlestown, N. H., crossing Cheshire Toll Bridge (15 cents) at about 1.5 miles. Bear right after crossing bridge and proceed south about 1.6 miles to Charlestown village, turning sharply left here on Routes 11 and 12, and proceed 0.8 miles northeast to Sunnhshire.

Exposure

Quartzite and quartz-conglomerate dipping northeasterly. The quartzites belong to the Clough formation on the lower limb of the Skitchewaug nappe.

STOP 9 On Routes 11 and 12 about 3.0 miles north of Stop 8.

Exposure

East and west of road are grey staurolite schists and thin-bedded micaceous quartzites of Littleton formation.

Note: Walk west 0.3 miles to conspicuous ledges (Rattlesnake Hill) overlooking Connecticut River and Skitchewaug Mountain, passing over inverted section through lower Littleton, Fitch and Clough formations en route. Ledges overlooking river are basal conglomerate of Clough formation. The rocks dip consistently west and are on the lower limb of the Skitchewaug nappe and upon the east limb of the open syncline which bends the axial plane of the nappe.

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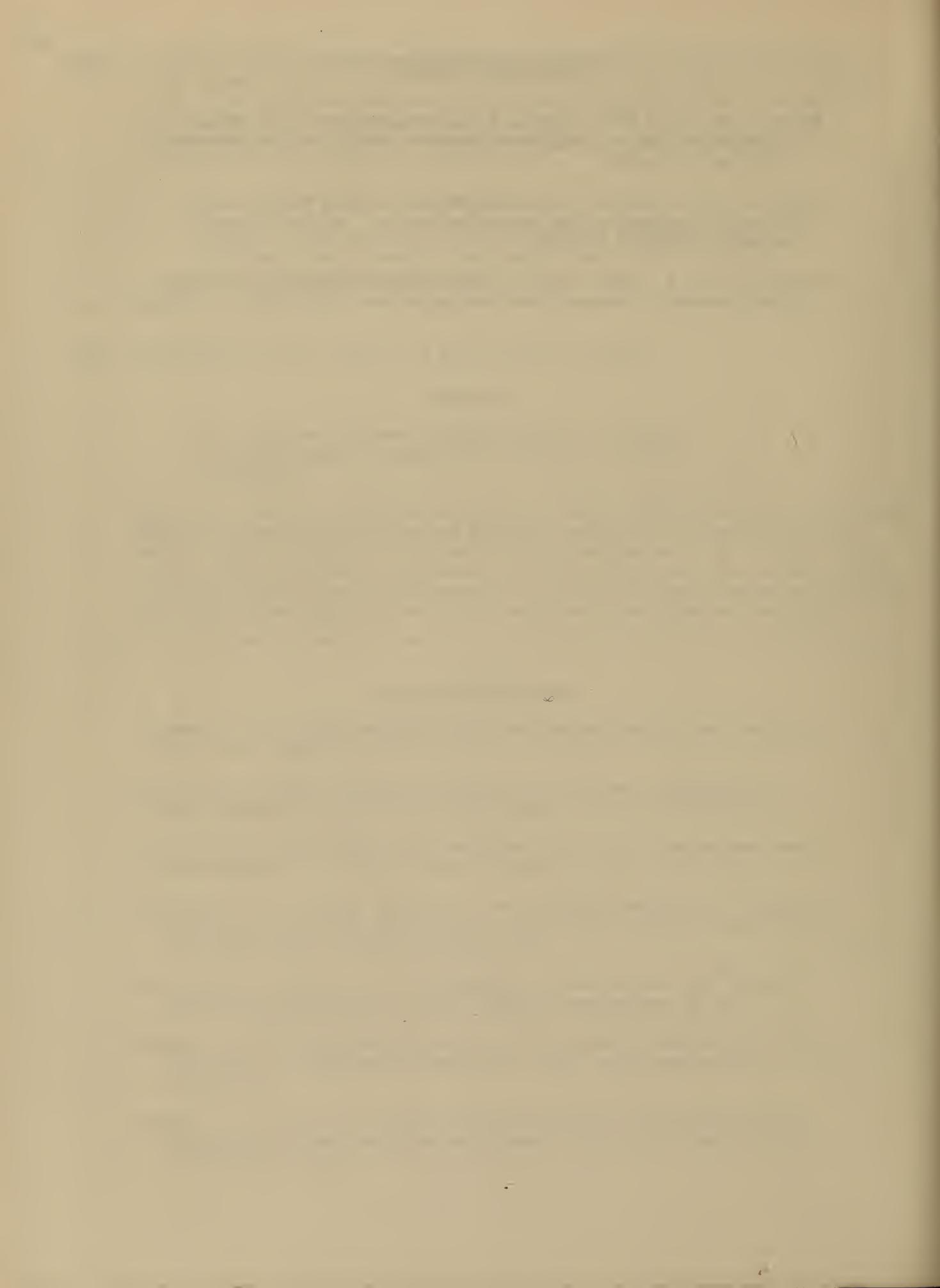
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TRIP F

GEOLOGY OF ASCUTNEY MOUNTAIN,
CLAREMONT QUADRANGLE, N. H. - VT.

LEGEND

ROCK TYPES

- ◻ Gneiss biotite granite
- ◻ Horneblende granite
- ◻ Biotite gneiss
- ◻ Pelite
- ◻ Horneblende-biotite gneiss
- ◻ Gabbro-diorite
- ◻ Volcanic rock
- ◻ Gneiss
- ◻ Schist

FOLIATION, SCHISTOSITY, AND LINEAR ELEMENTS

- 50 Strike and dip of foliation or schistosity
- 50 Strike of vertical foliation or schistosity
- Horizontal foliations
- Foliation or schistosity with linear elements
- Vertical foliation or schistosity with linear elements
- Horizontal foliation or schistosity with horizontal linear elements
- Foliation or schistosity with horizontal linear elements
- Foliation or schistosity with two linear elements
- Foliation or schistosity with two linear elements, one horizontal
- Linear element alone

FOLDS

- 50 Strike and dip of axial plane of fold with direction and value of plane of fold
- 50 Direction and vertical plunge of fold with vertical axial plane
- 50 Field with horizontal axis and vertical axial plane
- 50 Field with horizontal axis and dipping axial plane

- Village



Contour interval • 100 feet
Topography redrawn from Claremont, N.H. - Vi.
and Ludlow, Vi. quadrangles of the U.S.
Geological Survey



GEOLOGIC MAP OF ASCUTNEY MOUNTAIN, VERMONT

TRIP F

GEOLOGY OF ASCUTNEY MOUNTAIN, CLAREMONT QUADRANGLE, N. H. - VT. -
SUNDAY, OCTOBER 10, 1954 - 8:30 A.M.

Leader: Richard E. Stoiber

Assembly Point

Park gate, base of Mt. Ascutney auto road

To reach this point proceed from Hanover south to White River Junction and then on Route 5 south through Windsor, Vt. Turn abruptly right at a well-marked road on the right leading to Mt. Ascutney, approximately $3\frac{1}{2}$ miles south of Windsor, Vt. The Park gate is on the left 1.3 miles from the turn off Route 5. (This is about a 45-minute drive from Hanover.)

The group of cars will proceed up the toll road to a parking area near the top of the mountain. Each driver will pay for his own car--50 cents per car with five or less passengers.

General

Mt. Ascutney is composed of an assemblage of igneous rocks that have intruded highly-folded schists and gneisses of Pre-Cambrian and lower Paleozoic age. The intrusions, members of the White Mountain magma series, have had no significant structural effects on the country rock. Radioactive age determinations on the structurally and mineralogically similar Conway granite has established its age as 230 m.y. (Mississippian). The major intrusives are syenite, biotite granite, and gabbro-diorite. The gabbro-diorite stock lies to the west, the syenite stock to the east, and a granitic stock, circular in map plan, lies within the syenite. Exposures of each of these will be examined. Mt. Ascutney is the topographic expression of the syenite and granite. Arcuate and isolated irregular patches of volcanic rocks are found in the syenite high on the mountain. Devitrified felsite dikes intrude the surrounding metamorphics.

STOP 1 Parking area, end of auto road near top of Mt. Ascutney.

Exposure

Syenite of main stock

Basic inclusions in syenite (best seen at Stop 4)

Aplitic syenite

- - - - -

Questions:

1. Is the aplite of metasomatic origin. (?)

STOP 2 On the "Steep Trail" which leads from the parking area to the summit, several hundred yards below the summit.

Exposure

Volcanics

Syenite in contact with volcanics

- - - - -

Questions:

1. Nature of the syenite-volcanic contact.
2. Nature of the volcanics.

STOP 3 Summit of Mt. Ascutney (3144 ft. elevation).

Exposure

Syenite

Igneous breccia

Volcanics exhibiting flow structure

- - - - -

Questions:

1. Nature of the syenite adjacent to the volcanics.
2. Reason for the pockmarked weathered surface of some of the syenite.
3. Areal geology as seen from the summit.
4. Glacial grooving.

STOP 4 Return to cars and proceed down the mountain to a point 0.4 mile below summit parking area.

Exposure

Syenite with dark inclusions.

- - - - -

Note: The dark inclusions have been called xenoliths of basic rock greatly reworked by the magma (Chapman and Chapman). Daly described them as basic segregations.

Questions:

1. Nature of the inclusions.
2. Have inclusions a preferred orientation. (?)

STOP 5 Parking area, 0.9 miles below summit parking area, reached by a road to the left. We will walk back to the main road.

Exposure

Granite

Syenite

- - - - -

Questions:

1. Nature of the contact.

STOP 6 Proceed down the mountain, shifting to LOW GEAR 0.2 miles after leaving parking area, to a point 3.2 miles below summit parking area.

Exposure

Granite

Syenite

Miarolitic cavities

Basic inclusion (?)

Aplite

- - - - -

Questions:

1. Contact relationships.
2. Orientation of the miarolitic cavities.

Note: 0.1 miles down the road is syenite-schist contact (covered).

STOP 7 3.5 miles below summit parking area.

Exposure

Metamorphosed Gile Mountain formation (Ordovician?)

Quartzites and schists

- - - - -

Note: From here to the Park gate exposures on the left hand side of the road show less and less effect of contact metamorphism as indicated by the increased prominence of the schistosity.

STOP 8 Turn left at Park gate and follow black top road around the north side of the mountain. Turn left 6.3 miles from the gate house (19.3 miles from summit parking area) and proceed 0.7 miles to:

Exposure

Gabbro-diorite

Granite dikes

- - - - -

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